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Uncertainty in the Economics of Knowledge and Information

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The primary purpose of this book is to provide insight into the economics of intellectual property. It is useful to begin, however, by acknowledging that there is much that remains unknown about the primary ingredient in intellectual property: innovation. The research and development (R&D) process involves a high degree of uncertainty, which plays a significant role in both our understanding and analysis of innovation and technology markets.

To paraphrase Donald Rumsfeld, lack of information comes in three flavors: *known unknowns, unknown unknowns,* and *unknowable unknowns.*[1] In spite of decades of economic research and an accumulating wealth of data, there is much about R&D and innovation markets that still falls into these three categories.

The benefits of the innovative process are well-known: faster technological progress, higher productivity, and improved standards of living. The best method or appropriate policy for achieving these outcomes, however, remains an important question at the intersection of the economics of antitrust and intellectual property. Does intellectual property protection encourage faster innovation or slow the adoption of new and beneficial technologies throughout the economy? What is the proper role of antitrust policy in innovation and technology markets in order to enhance techno-

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1 Defense Department Daily Briefing, 22 February 2002: "Reports that say that something hasn't happened are always interesting to me, because as we know, there are known knowns; there are things we know we know. We also know there are known unknowns; that is to say we know there are some things we do not know. But there are also unknown unknowns—the ones we don't know we don't know."

logical progress?[2] Does competition in R&D lead to more or less innovation? How can we tell if innovation is strengthened or lessened?

The reality is that very little is known, or generally accepted among economists, about how competition in R&D affects the rate of innovation, how the rate and level of innovation affects technological progress and consumer welfare, or even how to distinguish economically efficient R&D from socially wasteful R&D. The high degree of uncertainty and debate concerning the appropriate policy governing information markets stems from uncertainty and heterogeneity inherent in the innovation process itself. An innovation, by definition, is something new and heretofore unseen or unthought-of. The very uniqueness of an invention that renders it patentable also renders its impact on the economy difficult to predict with precision. The goal of this chapter is to separate fact from rhetoric and to acknowledge the role that unknowable unknowns must play in our analysis of knowledge and information markets.

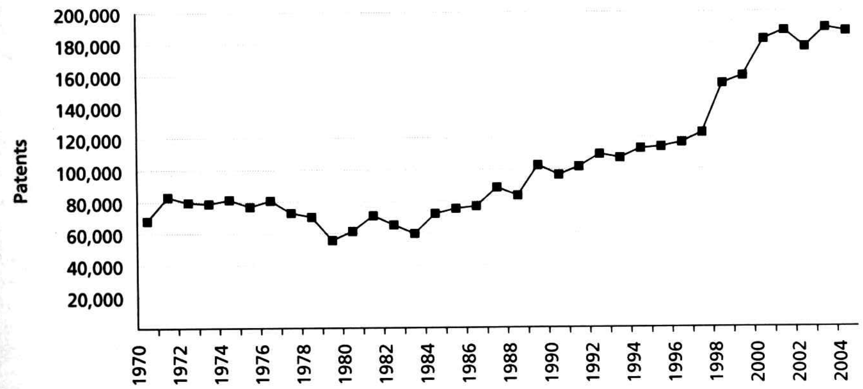
The Facts

Let us begin with what is known. Between 1970 and 2004 the number of patents granted per year in the U.S. almost tripled. Roughly 120,000 more patents were granted in 2004 than were granted in 1970 (Figure 1).[3] Not surprisingly, this tremendous growth in innovative output is matched by growth in the inputs to the innovative process. There has been significant growth in the U.S. both in the number of scientists and engineers working in research and development and in the amount of overall R&D spending (Figures 2 and 3). In real terms, more than twice is spent on R&D today than was spent 30 years ago. The output of this research is measurable by the corresponding increase in the number of patentable inventions. Yet, in spite of this surge in innovation, no obvious increase in trend GDP growth can be observed by charting the annual growth rate of the economy over the last three decades (Figure 4). This begs the question, where are the benefits of all of this research?

2 An innovation market is the market that arises prior to the realization of an invention. It is the market of trial and error in which R&D dollars are spent in the quest for knowledge. A technology market is the market that arises after the realization of an invention. It is the market in which intellectual property rights, or know-how, is traded.

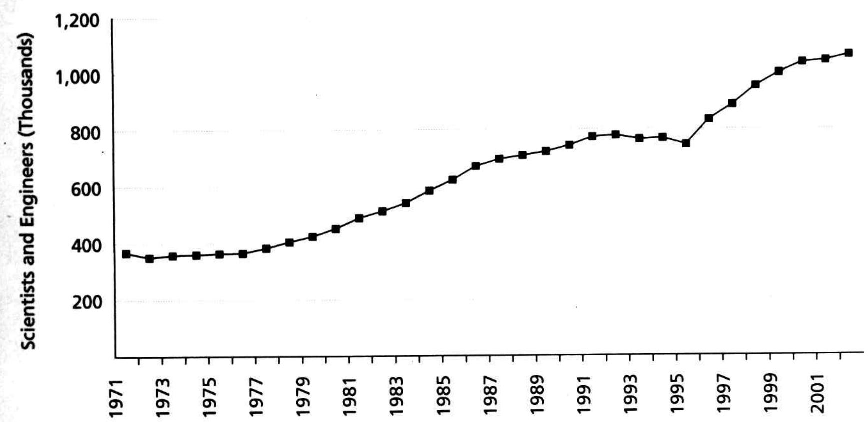
3 United States Patent and Trademark Office annual reports.

Figure 1. Growth in Innovative Activity



Sources: United States Patent and Trademark Office Annual Reports (www.uspto.gov/web/offices/com/annual/index.html) and table of issue years and patent numbers (for years 1970 to 1975) (www.uspto.gov/web/offices/ac/ido/oeip/taf/issuyear.htm).

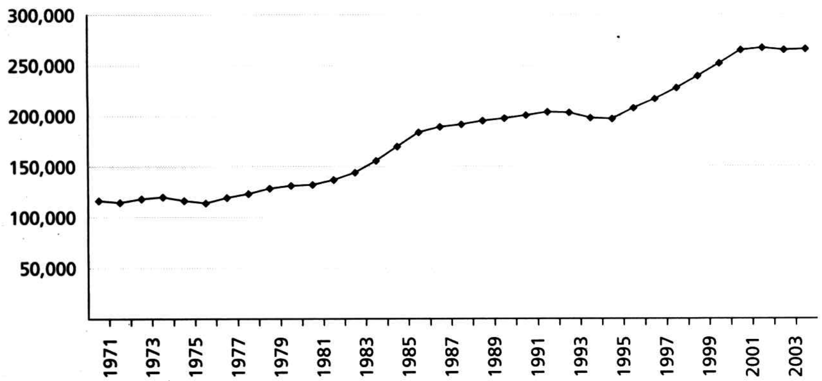
Figure 2. Growth in the Search for Innovations



Source: National Science Foundation (www.nsf.gov).

Note: As a result of a new sample design, statistics for 1988–91 have been revised since originally published, and statistics for 1991 and later years are not directly comparable with statistics for 1990 and earlier years.

igure 3. Growth in Real R&D Expenditures



urce: U.S. Department of Labor, Bureau of Labor Statistics (www.bls.gov/cpi/home.htm).

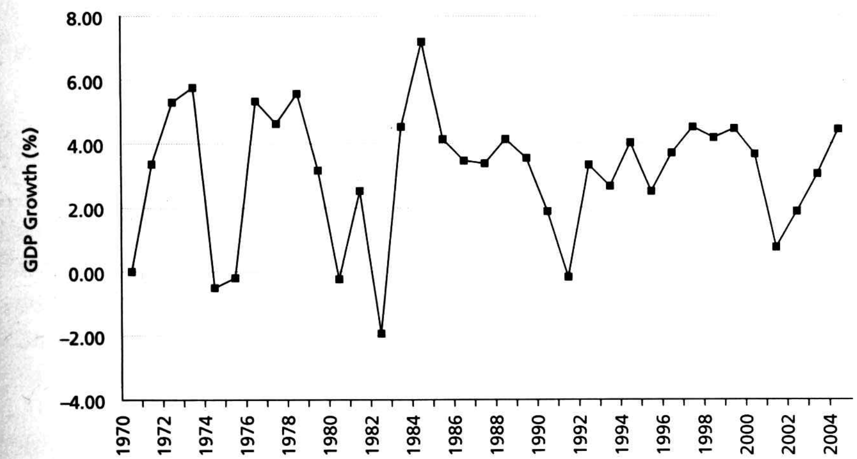
otes: R&D expenditures have been converted to real expenditures using a CPI conversion factor (base year=1967) for each year.

Economic theory tells us that more investment in R&D should lead to ore innovation and more innovation should fuel GDP growth.[4] We see ore investment in R&D, we see more innovation, but GDP appears to be rowing much as it always has. Moreover, in a series of studies in 1995, conomist Charles Jones empirically tested and rejected the predictions f economic models linking an increase in R&D to faster GDP growth.[5]

Why do we care? Among the topics of concern in intellectual property conomics is the role that antitrust policy should play in technology and nnovation markets. Does antitrust scrutiny, such as in cases like *Rambus*

See, for example, Paul M. Romer, "Endogenous Technological Change," *Journal of Political Economy* 98, no. 5 (October 1990); Gene M. Grossman and Elhanan Helpman, *Innovation and Growth in the Global Economy* (Cambridge, MA: MIT Press, 1991); Gene M. Grossman and Elhanan Helpman, "Quality Ladders in the Theory of Growth," *Review of Economic Studies* 58 (January 1991); and Phillipe Aghion and Peter Howitt, "A Model of Growth through Creative Destruction," *Econometrica* 60 (March 1992).
Charles Jones empirically tests and rejects the predictions of the economic models of Romer, Grossman and Helpman, and Aghion and Howitt. See Charles I. Jones, "Time Series Tests of Endogenous Growth Models," *Quarterly Journal of Economics* (1995); and Charles I. Jones, "R&D-Based Models of Economic Growth," *Journal of Political Economy* 103, no. 4 (1995).

Figure 4. GDP Growth Rate



***Source:** Bureau of Economic Analysis at the U.S. Department of Commerce (www.bea.doc.gov)*

***Notes:** Based on chained 2000 dollars.*

or *Genzyme*, enhance or retard innovation?[6] What will happen to the rate of innovation if investments in R&D are subject to antitrust regulation or if a patent owner's use of his intellectual property draws increased antitrust attention? The concern, rooted in well-founded economic theory, is that if antitrust policy limits the rewards that technology owners receive for their inventions, that will reduce incentives to invest in R&D, leading to fewer innovations and a slower rate of technological progress, potentially harming future consumer welfare. But is this really a concern, given our experience to date?

The Uncertainty

There are potentially many reasons why we do not see the link in the data between innovation and faster GDP growth. Chief among them is that perhaps we are using the wrong instruments to measure the impact of innovation. As discussed further and in the next chapter, the number of patents granted may be a poor measure of the level of innovation in an

6 See *In the Matter of Rambus Inc.*, F.T.C. Dkt. No. 9302; and *In the matter of Genzyme Corp./Novazyme Pharmaceuticals Inc.*, File No. 021 0026.

economy. Approximately 80 percent of patents granted represent improvements to products already in existence as opposed to inventions of wholly new products.[7] While some product improvements no doubt do improve consumer welfare, one cannot tell by counting patent grants which patents represent insignificant technological advances and which ones represent major technological breakthroughs.

Moreover, while Figure 4 may appear to yield no discernible trend in GDP growth since 1970, in fact, economic analysis has shown that 1995 marked the beginning of an increased pace of productivity growth.[8] This phenomenon has been referred to as the "new economy," and the higher rate of growth is attributed to technological progress, particularly in the computer-intensive sectors of the economy.[9] Prior studies failing to find a link between productivity growth and R&D may simply have been looking at a period when growth was slow for other reasons.

Even if economists were secure in the prediction that greater innovation leads to faster productivity growth and eventually to higher standards of living, we would still be left with uncertainty as to the best way to encourage greater innovation and what the appropriate antitrust and intellectual property policies should be.

Uncertainty regarding appropriate policy begins in the innovation market, where R&D is conducted in the search for patentable inventions. For innovation markets (e.g., *Genzyme*), there is uncertainty regarding whether competition in R&D (which means more firms focusing on the same research problem) leads to more or less innovation.[10] If it is a winner-take-all innovation market, such as those we see in the pharmaceutical industry, does the prospect of coming in second and having nothing that rewards the investment in R&D limit a firm's willingness to invest?

7 Nathan Rosenberg, "Uncertainty and Technological Change," in *Technology and Growth*, ed. J. C. Fuhrer and J. S. Little (Boston: Federal Reserve Bank of Boston, 1996), 96.

8 GDP is a measure of the output of an economy, whereas productivity measures output per hour worked. All else being equal, higher productivity growth means faster GDP growth.

9 See Kevin Stiroh, "Growth and Innovation in the New Economy," in *New Economy Handbook*, ed. Derek C. Jones (San Diego, CA: Academic Press, 2003), 723–751; and Dale W. Jorgenson, Mun S. Ho, and Kevin Stiroh, "Will the U.S. Productivity Resurgence Continue?" *Current Issues in Economics and Finance* 10, no. 13 (December 2004).

10 See, for example, Xiangkang Yin and Ehud Zuscovitch, "Is Firm Size Conducive to R&D Choice? A Strategic Analysis of Product and Process Innovations," *Journal of Economic Behavior and Organization* 35, no. 2 (April 1998); and Luis Cabral, "Bias in Market R&D Portfolios," *International Journal of Industrial Organization* 12, no. 4 (December 1994).

Or does competition spur firms to invest more and innovate faster to gain a competitive edge?

There is also uncertainty as to whether competition in R&D leads to economically *efficient* innovation.[11] Does competition lead to duplicative efforts and inefficiently spent research dollars? In other words, would the same invention be discovered more cheaply if only one firm or a government entity were running the necessary lab experiments and clinical trials?

Uncertainty continues past the innovation market stage and into the technology market—the market that arises after the patent has been granted. If antitrust regulation of technology markets lowers the return to innovation, we expect a reduction in the incentive to invest, but we do not know how that will affect the rate of growth of the economy. If investment is reduced, we do not know if firms will continue to invest in "important" inventions and scrap only research in "marginal" inventions. Moreover, there is uncertainty at the outset in determining what is an "important" investment and likely to lead to faster GDP growth and improve consumer welfare and what is a "marginal" investment likely to have little or no impact on technological progress. Ex ante we do not know which is which.

Uncertainty is inherent in the very process of inventing. One of the reasons that we may not see an obvious connection in historical data whereby more innovation leads to faster technological progress is simply that some inventions matter and some do not. The late professor Zvi Griliches declared patents a "shrinking yardstick" for measuring innovation. Adam Jaffe and Josh Lerner blame the patent system for granting too many patents on trivial, useless, or redundant inventions.[12] According to the authors, "the patent system—intended to foster and protect innovation—is generating waste and uncertainty that hinders and threatens the innovative process" by "increasing the costs of bringing new products and processes to market."[13]

While the invention of a watch that clocks time in dog years rather than human years[14] may be generally acknowledged to be of questionable economic value, it is not always immediately apparent which innovations

11 Kotar Suzumara, "Cooperative and Noncooperative R&D in the Presence and Absence of Spillover Effects," *American Economic Review* 82, no. 5 (December 1992).

12 Adam B. Jaffe and Josh Lerner, *Innovation and Its Discontents: How Our Broken Patent System Is Endangering Innovation and Progress, and What to Do About It* (Princeton, NJ: Princeton University Press, 2004).

13 Id., 2.

14 U.S. Patent 5,023,850, issued 11 June 1991.

contribute to the social welfare and which innovations serve only as a drain on the patent examiner's time and represent a larger opportunity cost for society.

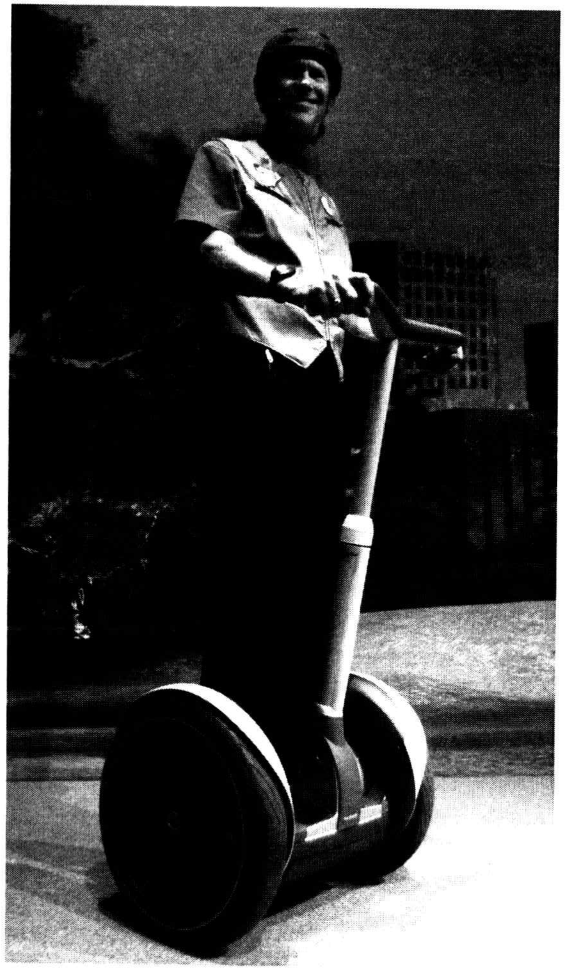
Uncertainty does not end when the invention is patented. Predicting the long run effects of an invention is as uncertain as predicting when and how your R&D will yield results. In 1943 the Chairman of IBM predicted that there was a world market for about five computers.[15] More than 30 years later the president of Digital Equipment Corporation fearlessly declared, "There is no reason for any individual to have a computer in their home."[16] These industry leaders were clearly wrong in their initial predictions. Identifying which inventions will spur growth and which will amount to a lot of noise and fury signifying nothing is no easy task. Even the executives who led the computer industry into its current age did not foresee the impact that technological progress in computers would have on productivity in the workplace and everyday life.

Clearly, some innovations will fuel technological progress, but one cannot predict with certainty which innovations those will be. On the one hand, computers and the associated technology achieved success far beyond initial expectations. On the other hand, there are inventions like the Segway (Figure 5). This top-secret invention, unveiled on national television in 2001, was hailed as a world-changing creation that would eventually replace cars in congested areas, causing no harm to the environment and costing less than five cents per day to operate.[17] *Time* magazine praised the invention, claiming, among other things, that it was impossible to fall off the vehicle.[18]

These predictions have, thus far, proven false. Sales of the Segway had only reached 6 percent of first-year forecasts when the Consumer Products Safety Commission recalled the device to correct a software problem that was causing riders to fall off.[19] The invention, while undoubtedly remarkable in its own right, has yet to have a significant impact on day-to-day life, productivity, or the growth rate of the economy, in spite of initial forecasts to the contrary.

15 Ernst R. Berndt, *The Practice of Econometrics: Classic and Contemporary* (Reading, MA: Addison-Wesley Publishing Company, 1991), 1.
16 Id.
17 Andy Sullivan, "Mysterious 'It' Invention Is a Motor Scooter, says *Time*," *Ottawa Citizen*, sec. A2, 3 December 2001.
18 Id.
19 David Armstrong, "The Segway: Bright Idea, Wobbly Business," *The Wall Street Journal*, sec. B1, 12 February 2004.

Figure 5. Segway



Source: Getty Images

There are other storied examples of our "inability to anticipate the future impact of...innovations, even after their technical feasibility has been established."[20] The inventor of the radio anticipated that it would be used only for ship-to-shore communications and not as an instrument for mass broadcast,[21] and Bell labs initially hesitated to apply for a patent

20 Nathan Rosenberg, "Uncertainty and Technological Change," 91.
21 Id., 94.

on the laser because the device had no apparent immediate relevance to the telephone industry.[22]

Famous failures are equally abundant. DuPont spent over $250 million to develop its synthetic leather, "Corfam," and showcased it as a miracle fabric at the 1964 world's fair. DuPont withdrew the product after seven years on the market because it failed to live up to initial expectations.[23] RJ Reynolds' smokeless cigarette was also a technical success but a commercial failure. After seven years in development and $325 million in R&D costs, the product was withdrawn after only four months on the market.[24]

Conclusion

The hallmark of the inventive process is uncertainty. We rarely know with certainty whether the research underway will yield a significant patent or a marginal one, whether an invention will have far reaching implications, or even whether a significant technological breakthrough will achieve market acceptance. These questions remain at the heart of the economics of knowledge and information and affect the way we think about the economics of intellectual property.

22 Id., 93.
23 Lee Neville, "A Synonym for Failure," *U.S. News & World Report*, 24 February 1997, 15.
24 Id.

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The Economics of Patent Policy: A Review of Recent Empirical Studies

John H. Johnson

Policy makers, company executives, and economists recognize that innovation is a fundamental source of economic growth and efficiency. Yet, the exact mechanism through which innovation accomplishes this feat is still not well understood. The study of patents and patent policy among economists is therefore well justified—intellectual property is a tangible link between innovative behavior and economic growth. Economists are exploring a number of issues related to patents. How valuable are patents? Is the number of patents a useful measure of innovative activity? How have changes in patent policy affected patenting behavior? What patents are most likely to be challenged in court? In this chapter, I highlight a sample of recent economic research papers that reflect the cutting edge of the economic analysis of patent policy.[1]

The Distribution of Patent Value

Economists routinely turn to market-based evidence when they attempt to value products, goods, and services, but valuing a patent presents particular challenges. In goods markets, value is measured by the price a product commands. Patents, though, are frequently not traded on markets, and therefore the "price" of the patent is often not observable. Moreover, while some patents may be licensed, the terms of licensing agreements are often not made public or are affected by factors other than

1 This review does not, however, address any papers using theoretical research techniques, such as modeling economic behavior to determine optimal patent policy. My focus on empirical papers in no way implies that theoretical analysis has not been important or useful for understanding patent issues; these studies are excluded only because they are beyond this chapter's scope. All of the papers in this chapter were selected from refereed economics journals, and most of them have been published in the last five years.